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Diesel and Solar Energies Costs Assessment under Drip Irrigation System

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ABSTRACT

Recently, there is an urgent need for clean energy (renewable energy) to replace traditional energy for irrigation purposes, especially in new reclamation lands. There is also an important question about how renewable energy can become cost-competitive. So, the aim of the current investigation is the cost estimation at operation of water pumping system via various technologies *i.e.*, photovoltaic and diesel systems under drip irrigation method. The experiments were done in a private farm located in Wadi El-Natrun desert represented the new reclamation lands in Egypt. The comparison 's findings indicated that the system cost of solar photovoltaic panels was less compared to the cost of the diesel generator system. Also, the water delivery for each kWh under the solar photovoltaic system is higher compared to that one of the diesel generator systems. Generally, it can be noticed that solar photovoltaic panels system possess a higher initial cost as compared to diesel systems. However, the solar photovoltaic panels system possess a lower recurring cost compared with the diesel system during the study period of time. The cost of solar energy/m^3 of extraction water under the solar photovoltaic panels system was about 0.36 LE/m^3 while using the convention diesel energy leads to cost of about 1.79 LE/m^3. Thus it can be noticed that the cost of utilization of solar energy represented by 20% of usage of diesel energy. Generally, this would encourage farmers to care to utilization of the solar photovoltaic panels system to operate ground wells. Finally, the collected an obtained data recommended using solar energy.

Keywords: cost estimation, photovoltaic, diesel, Wadi El-Natrun desert.

INTRODUCTION

Nowadays in Egypt, farmers have moved to the desert to exploit the enormous regions of unused land, where the utilization of traditional diesel pumps for irrigation purposes is common. This is due to that access to electric networks is limited in these remote areas (Abdelkhalek and King-Okumu, 2021).

Egypt's Solar Atlas indicated that Egypt is considered a sunbelt country with about 2,000 to 3,000 kWh per m^2 per year of direct solar radiation, where the sun shines 9-11 hours per day with few cloudy days Patlitzianas, (2011).

Solar irrigation pumps provide a great opportunity for Egyptians in these remote regions, which possess a shortage of electric networks as well as provide a sustainable life for Egyptian without depending on both conventional diesel and traditional electrical pumps (Sayed *et al.*, 2019).

On the other hand, access to groundwater resources which are essential for agricultural purposes can motivate farmers to move far away from the overcrowded regions around the Nile River to the new lands in the desert (Ayad *et al.*, 2021). In Egypt, the government subsidizes fossil energy prices; however, this will not be the case in the near future. Both gasoline and diesel prices will rise up, therefore it is time to head to the green power sources. Currently, the cultivation of new farms in the new reclamation lands of Egypt is a governmental aim, where the source of irrigation water in these farms is deep groundwater, and it is discharged to the 35 surfaces via electrical submerged pumps. The electricity can be offered using both traditional generators or PV panels. Traditional generators use gasoline or diesel fuel to work (Shouman *et al.*, 2018).

Armanuos *et al.*, (2016) reported that the type of power source should be considered when ranking pumping systems according to environmental performance, where they indicated that diesel-powered pumping systems were more harmful to the environment compared to solar power pumps.

Shouman *et al.*, (2016) studied three systems for water pumping; PV only, hybrid PV-Diesel and Diesel alone. The findings showed that diesel pumps were typically characterized by a lower capital cost simultaneously with a very high operation and maintenance cost, whilst on the contrary, solar energy was with a considerably higher capital cost simultaneously with very low ongoing operation and maintenance costs.

Until these moment, a little researches evaluating diesel or solar energy under drip irrigation system, So The current investigation economically analyzed the operation of the water pumping system via various technologies *i.e.*, photovoltaic PV and diesel under new lands reclamation in Egypt.

MATERIALS AND METHODS

The current investigation was performed in a private farm located in Wadi El-Natrun desert, Egypt (30° 35′ 00″ N and 30° 20′ 00″ E). The soil samples of this farm were taken at a depth of 0-25 cm to analyze relative to Sparks *et al.* (2020) for chemical properties and for physical properties using methods of Dane and Topp (2020) for physical properties. The soil of farm possess a sandy loam texture and contained 24.1% of coarse sand, 50.0 % of fine sand, 14.2%

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of silt and 11.7% of clay with saturation (SP) of 30.48, organic matter of 0.5%, calcium carbonate of 1.65 and pH of 8.13 and EC of 1.50 having $Ca^{2+,}$ Mg^{2+},Na^{+}, $K^{+,}$ HCO_3^{-}, Cl^{-} and SO_4^{2-} values of 1.52, 0.93, 4.73, 0.50, 1.61, 4.52 and 1.55 meq per 100g soil, respectively.

System Energy

Two different sources of electrical energy for driving the water pump were proposed;

a- The first was the diesel unit, where it gives the needed energy for pumping water only. Fig 1 illustrates the system of diesel energy water pumping.

b- The first was PV water pumping system, where the required electrical energy is generated only from the solar energy through PV panels in sunshine hours in addition to the drive of the water pump is done by the pump controller. Figs 2 and 3 illustrate the main components of the PV water pumping system as a schematic diagram as well as the solar panels and the transformer system in the studied farm. Solar panels were collected of smaller solar cells which are predominantly made using crystalline silicon (more mature technology), where increasing module temperature will reduce power output from the panel In this type of panel). The cell possessed a very dark blue almost black appearance as well as no perceivable cell division lines. The individual solar cell was a 6" x 6" square, where 60-cell panels were laid out in a 6×10 grid.

Fig. 1. Diesel energy water pumping system

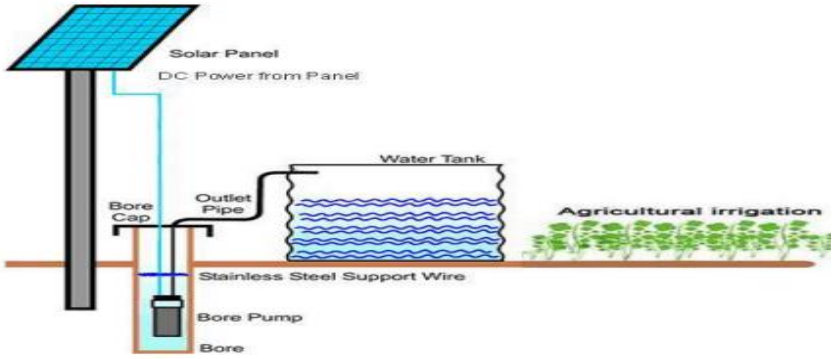

Fig. 2. PV water pumping system (A Schematic diagram)

Fig. 3. Solar energy water pumping system

Economically estimation

The study analyzed the operation of both systems from the economical view depending on the components of each system and all considered costs.

System cost

A system cost for operating a farm was prepared using either PV panels or the traditional generators in the generation of electricity needed for the submerged pumps. A comparison between both systems using cost estimation was done to define a better economic system.

To execute the economical estimation, the following assumption, parameters and limitations were considered;

PV system: The study period was 25 years where the operating life of the PV panels can be assumed to be 25 years. While 10 years for life of diesel generator (diesel generator should be replaced every 10 years). The initial cost of the photovoltaic system is 212000 LE (year of 2018) (Table 1) including 36.0 panels of 70 kW with system guarantee for 25 years provided by the company in addition to cables, converter and the installation cost with efficiency as 80%. The stainless steel pump (15 kW) cost was 22,000 LE, and well drilling, inner and outer tubes (3.0 and 11.0 inches) costs of 52,000 LE (Shouman *et al.,* 2018).

Diesel system: Initial cost of diesel generator was 165,000 LE under free installation. The cast iron pump (30 kW) was 15,000 LE, and well drilling, inner and outer tubes (4.0 and 11.0 inches) costs of 52,000 LE. Also, the cost of the annual maintenance was 4.5% of total capital cost almost for diesel generator. Cost of diesel fuel as well as its transportation simultaneously are140 LE. The consumption of diesel fuel for 30 kW hr. engine was 6.0 gallons day^{-1}, where the operating hours year^{-1} were 2240 hr year $^{-1}$.The annual cost of fuel (ACF) was calculated as the following equation:

ACF = No. of fuel gallons day^{-1}× Cost of diesel fuel× No. of operating hours per year^{-1}

The annual cost of labors (ACL) was calculated as the following equation: ACL = Cost of labor month^{-1}× 12 months.

The annual cost of fuel consumption (ACF) is 235,200 LE, whist the annual cost of oil consumption was 3.0 % of ACF. The annual cost of labors (ACL) is 42000 LE (Armanuos *et al.,* 2016 and Shouman *et al.,* 2016 and 2018).

Specification of Diesel and Solar Energy Water Pumping.

- **Photovoltaic system (PV).**

The design of any PV system depends on the site traits like solar irradiance and No. of sunshine hours with the temperatures. The PV water pumping system consists of a cabinet, PV panels, mechanical structure, pump, pump controller and, cables. Table 1 shows the specification of the system and pump under photovoltaic system (PV).

Table1. Specification of the system and pump.

Parameters		values
System	Initial cost of solar PV panel	212000 LE
	The power of each panel	15 kW
	Number of PV panel	36 Panel
	Pump flow rate	14 liter per sec
Pump	Initial cost of pump	165000 LE
	Pump flow rate	21 liter per sec
	Power of pump	30 kW

- **Diesel System**

Diesel unit used the fuel to drive the water pump. Therefore, the total cost of the system includes many factors *i.e.,* cost of the diesel unit, fuel, oil, submersible, pump and maintenance. Table 2 shows the specification of diesel system.

Table 2. Specification of diesel system.

Parameters	values
Initial cost of generator	113000 LE
Power	30 kW
Diesel fuel consumption	6.0gallon hour $^{-1}$

RESULTS AND DISCUSSION

Cost Estimation of Diesel and Solar Energy Water Pumping:

Data in Table 3 shows the comparison‘s findings indicating that the system cost of solar photovoltaic panels was less compared to the cost of diesel generator system. This means that a solar photovoltaic panel was economic comparing with a diesel generator taking in to consideration the system's time considered in this investigation.

Table 3. Cost categories for both irrigated pump systems.

Categories of cost	Cost, thousand LE	
	Diesel system	PV system
Capital Cost (CC)	165	212
Equipment	113	167
Drilling well and pipes	52	45
Energy cost as annual cost	242.256	0.0
Maintenance as annual cost	7.425	0.0
Labors cost as annual cost	42	42

Tables 4 and 5 illustrate the total cost of both considered systems for each hour, where it can be clearly said that the water delivery for each kWh under solar photovoltaic system is higher compared to that one under the diesel generator system (Table 4). The reason behind that may be attributed to that the needed photovoltaic power for the operating system is less comparing with the needed diesel generator power. On the other hand, the cost of irrigation water for each cubic meter under solar photovoltaic system is less compared to that under the diesel generator system (Table 5).

Table 4. Cost comparison of both investigated systems.

Categories of cost	Cost LE hr^{-1}	
	Diesel system	PV system
Operating costs	18.36	134.36
Fixed costs	3.78	7.36
Recurring costs	14.58	127

Table 5. Parameters of water pumping system.

Categories of cost	Cost, thousand LE	
	Diesel system	PV system
Water cost, LE/ m^3	0.36	1.79
Water flow rate, m^3 /hr	50	75

From the same Tables indicate, it can be noticed that solar photovoltaic panels system possess higher initial cost as compared to diesel system. However, the solar photovoltaic panels system possess lower recurring cost comparing with the diesel system during the study period of time. This trend could be attributed to the system guarantee including costs of both maintenance and replacement.

On other hand, if the investigation considered that prices of fuel are raising, these numbers could keep going up. Also, the data in Table 5 show that the cost of solar energy/m^3 of extraction water under the solar photovoltaic panels system was about 0.36 LE/m^3 while using the convention diesel energy leads to cost of about 1.79 LE/m^3. Thus it can be noticed that the cost of utilization of solar energy represented by 20% of usage of diesel energy. Generally, this would encourage farmers to care to utilization of the solar photovoltaic panels system to operate ground wells.

CONCLUSION

It can be concluded that the solar photovoltaic panels system possess a higher initial cost as comparing with the diesel generator. However, the first system (P.V.) possess a lower recurring cost compared to the traditional system (diesel generator) during the study period. Therefore, we recommended using solar energy.

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تقييم تكاليف طاقة الديزل والطاقة الشمسية تحت نظام الري بالتنقيط

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في الآونة الأخيرة أصبح هناك حاجه ملحه لكي تحل الطاقة النظيفة (الطاقة المتجددة) محل الطاقة التقليدية في أغراض الري خصوصا في الأراضي الجديدة. ايضا هناك سؤال مهم حول كيفية أن تصبح الطاقة المتجدّدة متنافسة من حيث التكاليف. لذلك، فإن الهدف من البحث هو التحليل الاقتصادي لتشغيل نظام ضخ المياه من خلال تقنيات مختلفة مثل أنظمة الطاقة الشمسية والديزل في عملية الري بالتنقيط في مزرعة خاصة تقع في صحراء وادي النطرون وتمثل أراضي الاستصلاح الجديدة في مصر. أشارت نتائج المقارنة إلى أن تكلفة نظام الألواح الشمسية الكهروضوئية كانت أقل مقارنة بتكلفة نظام مولدات الديزل. كما أن إيصال المياه لكل كيلو وات في ساعة تحت نظام الطاقة الشمسية الكهروضوئية أعلى مقارنةً بتلك الموجودة في نظام مولدات الديزل. بشكل عام، يمكن ملاحظة أن نظام الألواح الكهروضوئية الشمسية يمتلك تكلفة أولية أعلى مقارنة بأنظمة الديزل. ومع ذلك، فإن نظام الألواح الشمسية الكهروضوئية يمتلك تكلفة متكررة أقل مقارنة بنظام الديزل خلال فترة الدراسة.بلغت تكلفة الطاقة الشمسية للمتر المكعب من المياه المستخرجة تحت نظام الألواح الشمسية الكهروضوئية حوالي 0.36 جنيه لكل متر مكعب بينما استخدام طاقة الديزل التقليدية يؤدي إلى تكلفة حوالي 1.79 جنيه لكل متر مكعب. وبذلك يمكن ملاحظة أن تكلفة استخدام الطاقة الشمسية تمثل 20٪ من استخدامات طاقة الديزل. بشكل عام، سيشجع هذا المزارعين على الاهتمام باستخدام نظام الألواح الشمسية الكهروضوئية لتشغيل الآبار الأرضية. وأخيرًا، أوصت البيانات التي تم جمعها باستخدام الطاقة الشمسية.